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On the wind energy in Turkey

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ABSTRACT

Increase in negative effects of fossil fuels on the environment has forced many countries, including Turkey, to use renewable energy sources. Today, clean, domestic and renewable energy is commonly accepted as the key for future life, not only for Turkey but also for the world. As wind energy is an alternative clean energy source compared to the fossil fuels that pollute the atmosphere, systems that convert wind energy to electricity have developed rapidly. Turkey is an energy importing country, more than half of the energy requirement has been supplied by imports. Turkey's domestic fossil fuel resources are extremely limited. In addition, Turkey's geographical location has several advantages for extensive use of wind power. In this context, renewable energy resources appear to be one of the most efficient and effective solutions for sustainable energy development and environmental pollution prevention in Turkey. Since wind energy will be used more and more in the future, its current potential, usage, and assessment in Turkey is the focus of the present study. The paper not only presents a review of the potential and utilization of the wind power in Turkey but also provides some guidelines for policy makers.

Contents

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1. Introduction

The combined effect of the widespread depletion of fossil fuels and the gradually emerging consciousness about environmental degradation has given priority to the use of conventional and renewable alternative energy sources such as wind, hydro, geothermal, solar and bioenergy sources. The rapid development in wind energy technology has made it an alternative to conventional energy systems in recent years and wind power as a potential energy has grown at an impressive rate in Turkey.

The Republic of Turkey, located in Southeastern Europe and Southwestern Asia (that portion of Turkey west of the Bosporus is geographically part of Europe), has an area of about 780,580 sq km and a population of over 70 million [1]. With its young population, growing energy demand per person, fast growing urbanization and economic development; Turkey has been one of the fast growing power markets of the world for the last two decades. Turkey is an energy importing country; more than half of the energy requirement has been supplied by imports.

The energy sources can be split into three categories: fossil fuels, renewable sources, and nuclear sources. In this paper, the focus will be on renewable sources, specifically wind energy, in Turkey. However, before getting into details of wind energy use in Turkey, let me concentrate on the definition of "renewable source". In this paper, an energy source is regarded as renewable if it has the following two distinctive qualifications:

- Carbon neutral,
- Derived from those natural, mechanical, thermal and growth processes that repeat themselves within our lifetime.

Based on this definition, examples of renewable energy sources include wind, hydro, geothermal, solar and bioenergy sources.

Wind energy, like most terrestrial energy sources, comes from solar energy. Solar radiation emitted by the sun travels through space and strikes the Earth, causing regions of unequal heating over land masses and oceans. This unequal heating produces regions of high and low pressure, creating pressure gradients between these regions. The second law of thermodynamics requires that these gradients be minimized-nature seeks the lowest energy state in order to maximize entropy. This is accomplished by the movement of air from regions of high pressure to regions of low pressure, what it is known as wind. Large-scale winds are caused by the fact that the Earth's surface is heated to a greater degree at the equator than at the poles. Prevailing winds combine with local factors, such as the presence of hills, mountains, trees, buildings, and bodies of water, to determine the particular characteristics of the wind in a specific location. Because air has mass, moving air in the form of wind carries with it kinetic energy. A wind turbine converts this kinetic energy into electricity. The energy content of a particular volume of wind is proportional to the square of its velocity. Thus, a doubling of the speed with which this volume of air passes through a wind turbine will result in roughly a four-fold increase in power that can be extracted from this air. In addition, this doubling of wind speed will allow twice the volume of air to pass through the turbine in a given amount of time, resulting in an eight-fold increase in power generated. This means that only a slight increase in wind velocity can yield significant gains in power production [2].

By the first decade of the 21st century, wind power had become the best hope for the future of alternative energy. Of all the possible "new" sources of electricity, it had rather unexpectedly found itself the most touted and fastest growing alternative energy resource in the world, generating significant amounts of electricity in several countries. Now a global multi-billion-dollar industry, wind energy is regaining its once prominent place in the energy industry. For millennia, wind power has been used for everything from kite flying and propulsion to grinding and pumping, but never before has it been so important for the generation of electricity. It is an old resource applied to a new mission with unprecedented success. This article describes the development of wind energy in Turkey as of May 2008. The rest of the study is organized as follows. Section 2 introduces the key indicators of Turkish economy and her energy sector. Section 3 describes the current status of bioenergy in Turkey, while Section 4 focuses on wind energy economics. Following section presents an assessment of wind energy use, including its benefits and drawbacks. Then, some guidelines for policy makers are provided in Section 6 based on the findings of the study. Finally, Section 7 gathers the main conclusions derived from the paper.

2. Key indicators of Turkish economy and energy sector

Turkey's dynamic economy is a complex mix of modern industry and commerce along with a traditional agriculture sector that still accounts for more than 35% of employment. It has a strong and rapidly growing private sector, yet the state still plays a major role in basic industry, banking, transport, and communication. Real Gross National Product (GNP) growth has exceeded 6% in many years, but this strong expansion has been interrupted by sharp declines in output in 1994, 1999 and 2001 due to economic crisis. The economy is turning around with the implementation of economic reforms and 2004 Gross Domestic Product (GDP) growth reached 9%, followed by roughly 5% annual growth from 2005 to 2006. Inflation fell to 7.7% in 2005, a 30-year low, but climbed back to 9.8% in 2006. Despite the strong economic gains from 2002 to 2006, which were largely due to renewed investor interest in emerging markets, IMF backing, and tighter fiscal policy, the economy is still burdened by a high current account deficit and

Table 1
Selected indicators for Turkey (2004).

Indicator	Value
Population (million)	71,158,647 (July 2007 est.)
Population growth rate	1.04% (2007 est.)
GDP (purchasing power parity)	$640.4 billion (2006 est.)
GDP (official exchange rate)	$361.1 billion (2006 est.)
GDP real growth rate	6.1% (2006 est.)
GDP per capita (PPP)	$9100 (2006 est.)
Electricity production	154.2 billion kWh (2005)
Electricity consumption	129 billion kWh (2005)
Electricity consumption/population (kWh/capita)	1766.00
CO_2 emissions[a] (Mt of CO_2)	209.45

[a] CO_2 emissions from fuel combustion only. Emissions are calculated using IEA's energy balances and the revised 1996 IPCC guidelines.

Table 2
Energy balances for Turkey (2004).

Supply and consumption	Coal	Crude oil	Petroleum products	Gas	Nuclear	Hydro	Geothermal, solar, etc.	Combustibles renewables and waste	Electricity	Heat	Total[a]
Production	10531	2224	0	566	0	3963	1271	5557	0	0	24111
Imports	11200	23748	10481	18117	0	0	0	0	40	0	63587
Exports	0	0	−5289	0	0	0	0	0	−98	0	−5387
International marine bunkers[b]	0	0	−1005	0	0	0	0	0	0	0	−1005
Stock changes	648	−183	115	20	0	0	0	0	0	0	599
TPES	22379	25789	4302	18704	0	3963	1271	5557	−59	0	81905
Transfers	0	0	0	0	0	0	0	0	0	0	0
Statistical differences	−64	191	0	0	0	0	0	0	0	0	126
Electricity plants	−8701	0	−764	−7964	0	−3963	−85	−21	12436	0	−9063
CHP plants	−75	0	−1131	−3028	0	0	0	−5	524	450	−3265
Heat plants	−532	0	0	0	0	0	0	0	0	0	−532
Gas works	0	0	0	0	0	0	0	0	0	0	0
Petroleum refineries	0	−26065	26534	0	0	0	0	0	0	0	469
Coal transformation	−1910	0	0	0	0	0	0	0	0	0	−1910
Liquefaction plants	0	0	0	0	0	0	0	0	0	0	0
Other transformation	0	85	−85	0	0	0	0	0	0	0	0
Own use	−302	0	−1706	−100	0	0	0	0	−615	0	−2724
Distribution losses	−27	0	0	−19	0	0	0	0	−1999	0	−2045
TFC	10766	0	27150	7594	0	0	1186	5530	10287	450	62962
Industry sector	8361	0	4460	2178	0	0	121	0	4992	0	20112
Transport sector	0	0	13079	105	0	0	0	0	63	0	13246
Other sectors	2405	0	5858	4881	0	0	1065	5530	5233	450	25420
Residential	2405	0	2879	3640	0	0	1065	5530	2375	0	17894
Commercial and public services	0	0	0	1240	0	0	0	0	2522	0	3763
Agriculture/forestry	0	0	2979	0	0	0	0	0	318	0	3297
Fishing	0	0	0	0	0	0	0	0	17	0	17
Non-specified	0	0	0	0	0	0	0	0	0	450	450
Non-energy use	0	0	3754	430	0	0	0	0	0	0	4184
Of which petrochemical feedstocks	0	0	1406	430	0	0	0	0	0	0	1836

In thousand tonnes of oil equivalent (ktoe) on a net calorific value basis.
[a] Totals may not add up due to rounding.
[b] International marine bunkers are not subtracted out of the total primary energy supply for world totals.

high debt. Prior to 2005, foreign direct investment (FDI) in Turkey averaged less than $1 billion annually, but further economic and judicial reforms and prospective European Union (EU) membership are expected to boost FDI. Privatization sales are currently approaching $21 billion [1].

Turkey's population of more than 70 million is growing at an annual rate of 1.04% and expected to grow to 83.4 million in 2022. In response to the growth rates of population and consumption, Turkey's total final energy consumption (TFC) grew at an average annual rate of 9.6% over the last three decades. This average annual growth rate of TFC is projected to decrease to 5.4% between 2005 and 2010 and 7% between 2010 and 2020 [3]. Table 1 presents some important selected indicators for Turkey as of 2004 [1].

Turkey's primary energy sources include hydropower, geothermal, lignite, hard coal, oil, natural gas, wood, animal and plant wastes, solar and wind energy. In 2004, primary energy production and consumption has reached 24.1 million tonnes (Mt) of oil equivalent (Mtoe) and 87.8 Mtoe, respectively. Table 2 shows the Turkey's energy balance table in 2004. Fossil fuels provided about 86.9% of the total energy consumption of the year 2004, with oil (31.5%) in first place, followed by coal (27.3%) and natural gas (22.8%). Turkey has not utilized nuclear energy yet.[2] The Turkish coal sector, which includes hard coal as well as lignite, accounts for nearly one half of the country's total primary energy production (43.7%). The renewables collectively provided 13.2% of the primary energy, mostly in the form of combustible renewables and wastes (6.8%), hydropower (about 4.8%) and other renewable energy resources (approximately 1.6%) [4].

As can be seen in Table 3, the general equilibrium of energy use and supply indicators shows that Turkey is dependent on import resources very heavily. In 2004, 77.6% of the total energy supply was met by imports, and the rest was domestically produced.

Turkey's total electricity production and installed capacity were 162.5 GWh and 38.8 MW, respectively, in 2005 [5]. The distribution of the produced electricity energy according to primary energy sources was as follows: natural gas 44.74%, hydropower 25.11%, coal 25.05%, oil 4.92%, biomass 0.09%, geothermal 0.06% and *wind 0.04%* [6]. Table 3 reflects the increasing reliance on natural gas[3] in the power sector. The share of natural gas power plants in installed capacity was about 37% in 2005. Likewise, natural gas had the largest share in gross electricity output in 2005.

3. Current status of wind energy

3.1. Wind energy in the world

The wind has played a long and important role in the history of human civilization. Since earliest recorded history, wind power has been used to move ships, grind grain and pump water. There is evidence that wind energy was used to propel boats along the Nile

[2] For a more in depth discussion of nuclear energy in Turkey, see Erdogdu [18].

[3] Turkey imports 96.9% of her natural gas consumption.

Table 3
Installed capacity and electricity generation in Turkey (2005).

Fuel type	Installed capacity (MW)	%	Electricity generation (GWh)	%
Natural gas	14,199	36.58	72,700	44.74
Hydropower	12,906	33.25	40,800	25.11
Coal	9,117	23.49	40,700	25.05
Oil	2,527	6.51	8,000	4.92
Biomass	28	0.07	150	0.09
Geothermal	23	0.06	90	0.06
Wind	**20**	**0.05**	**60**	**0.04**
Total	38,820	100	162,500	100

Table 4
Electricity generation costs by fuel type (cent/kWh).

Power source	Minimum	Maximum
Large hydro	3.0	13.0
Small hydro	4.0	14.0
Municipal solid wastes	4.2	6.3
Bio mass	4.2	7.9
Natural gas	4.3	5.4
Coal	4.5	7.0
Agricultural residues	4.5	9.8
Wind	**4.7**	**7.2**
Geothermal	4.7	7.8
Hydraulic	5.2	18.9
Nuclear	5.3	9.3
Solar thermal hybrid	6.0	7.8
Wave/tidal	6.7	17.2
Energy crops	10.0	20.0
Solar PV	28.7	31.0

River as early as 5000 B.C. The western world discovered wind power much later. The earliest written references to working wind machines date from the 12th century. These were used for milling grain. It was not until a few 100 years later that windmills were modified to pump water and reclaim much of Holland from the sea. The first person, who generated in 1891 electricity from wind speed, was the Dane Poul LaCour, who lived in Denmark. Danish engineers improved the technology during World Wars I and II and used the technology to overcome energy shortages. In Europe, windmill performance was constantly improved between the 12th and 19th centuries. By 1800, about 20,000 modern European windmills were in operation in France alone. And in the Netherlands, 90% of the power used in industry was based on wind energy. Industrialization then led to a gradual decline in windmills, but even in 1904 wind energy provided 11% of the Dutch industry's energy needs and Germany had more than 18,000 units installed. As late as the 1920s, Americans used small windmills to generate electricity in rural areas without electric service. The popularity of windmills in the US reached its peak between 1920 and 1930 with about 600,000 units installed [7].

The popularity of using the energy in the wind has always fluctuated with the price of fossil fuels. When fuel prices fell after World War II, interest in wind turbines disappeared. But when the price of oil skyrocketed in the 1970s, so did worldwide interest in wind turbine generators. The wind turbine technology R&D that followed the oil embargoes of the 1970s refined old ideas and introduced new ways of converting wind energy into useful power. Many of these approaches have been demonstrated in "wind farms" or wind power plants – groups of turbines that feed electricity into the utility grid – in the US and Europe. The wind technology was improved step by step since the early 1970s. By the end of the 1990s, wind energy has re-emerged as one of the most important sustainable energy resources. The last decade was characterized by rough development of wind power engineering all over the world. The average annual increment in installed wind turbines capacity has been more than 39%. No other branch of power engineering did develop with such high rates. Today, the lessons learned from more than a decade of operating wind power plants, along with continuing R&D, have made wind-generated electricity very close in cost to the power from conventional utility generation in some locations. Table 4 presents electricity generation costs by fuel type [8] and ranges of investment and generation costs are provided in Table 5 for renewable sources [9].

As can be seen from the tables, electricity produced from wind is in general still more costly than that from fossil fuels. However, the gap is almost closed. For instance, if we regard the cost of producing electricity from natural gas as 100 units, that from wind is 109.3 units. That is, wind power is only about 9.3% more expensive than power from natural gas. Moreover, among renewable sources, wind comes third after hydro and bio power as the least expensive power source.

In October 2005, EU opened accession negotiations with Turkey, who has been an associate member of the EU since 1963 and an official candidate since 1999. There are many policies, directives, standards and norms in the EU designed to stimulate and support the wind power industry. The European Commission in its White Paper on Renewable Sources of Energy has set the goal of achieving a 12% penetration of renewables in the EU by 2010. One of the targets of the White Paper is to increase the EU electricity production from renewable energy sources from 337 TWh in 1995 to 675 TWh in 2010. Within this target the goal for wind energy is 40,000 MW of installed capacity in 2010, which could produce 80 TWh of electricity and save 72 Mt of CO_2 per year. Moreover, in all European countries, production of electricity from renewable resources is supported. In many countries minimum price system is used widely, which requires an electricity utility to purchase a portion of its electricity requirement, named as green energy, at a minimum price defined. Legally defined minimum prices change according to the country, some of them are shown in Table 6 [10].

Total world installed wind power capacity reached 58,982 MW at the end of 2005. There is an increasing trend in installed wind energy and average increasing rate was 28% over 1996–2005

Table 5
Ranges of investment and generation costs in 2002 and 2010 ($/kW).

	Low investment costs		High investment costs		Low generation costs		High generation costs	
	2002	2010	2002	2010	2002	2010	2002	2010
Small hydro power	1000	950	5000	4500	2–3	2	9–15	8–13
Solar photovoltaic power	4500	3000	7000	4500	18–20	10–15	25–80	1840
Concentrating solar power	3000	2000	6000	4000	10–15	6–8	20–25	10–12
Biopower	500	400	4000	3000	2–3	2	10–15	8–12
Geothermal power	1200	1000	5000	3500	2–5	2–3	6–12	5–10
Wind power	**850**	**700**	**1700**	**1300**	**3–5**	**2–4**	**10–12**	**6–9**

Table 6
Minimum price of wind electricity in some European countries (Euro cent/kWh).

Country	Price
Netherlands	9.6–9.9
France	8.4
Austria	7.8
Portugal	7.5–7.9
Greece	6.4
Spain	6.3–7.5
Germany	6.2–8.5
Turkey	5.0–5.5

period. It is estimated that installed wind power will reach to 120,000 MW in 2010. Approximately 69% of the installed wind capacity of the world is in the Europe, 17% in America and 12% in Asia. However, Germany has the highest installed wind capacity with 18,427.5 MW, which equals the 45% of European and 31.2% of world installed capacity. The top five wind energy markets are listed in Table 7 between 2000 and 2005 [10].

As it is seen from Table 7, Spain shows the highest development in installed wind energy capacity with 348.6% between 2000 and 2005. India, USA and Germany have also high development with 279.6, 258.2 and 201.4%, respectively.

3.2. Wind energy utilization and potential in Turkey

Turkey has a land surface area of about 781 thousand km^2. Surrounded by mountains, her unique geographical character creates a regular and moderate air inflow through her mountainous straits and passages. Its location between the colder European and warmer Asian and African systems also causes a wide variety of temperature and climate difference. Based on the examination of the Wind Atlas of Turkey,[4] it may be concluded that the regions of Aegean, Marmara, and East-Mediterranean have high wind energy potential. Turkey's annual theoretically available potential for wind power is calculated to be more than 80,000 MW,[5] about 10,000 MW of which is also economically feasible. As can be seen in Table 8, Turkey has the highest share with 166 TW/year[6] in technical wind energy potential among European countries [11]. However, in total, Turkey is slightly above the world average in terms of share of renewables in total primary energy supply. Table 9 presents renewables indicators by country for 2004 [12].

In Turkey, electricity generation through wind energy for general use was first realized in Izmir in 1986 with a 55 kW nominal wind energy capacity. However, the utilization of wind energy in Turkey has increased since 1998 when the first wind power plant with a total capacity of 1.5 MW was installed. Up to date, Turkey has about 200 MW wind power installed capacity in operation and about 600 MW under construction. Also, EMRA issued licenses for about 2500 MW wind power capacity and license applications for a total capacity of 77,871.4 MW[7] have been submitted to EMRA by private developers as of November 2007 [13]. Table 10 shows historical development of wind power in Turkey [14]. Annual average wind

[4] Taking into account the giant perspectives of utilization of wind energy, Turkish scientists carried out during last 10 years many investigations in various promising territories of Turkey. As a result of efforts of the General Directorate of Electrical Power Resources Survey and Development Administration (EIE) and State Meteorology Organization, *Wind Atlas of Turkey* was published. Wind speed data registered at EIE stations show that Turkey has sufficient wind energy potential, which exceeds the potential of hydropower which is estimated to be 35,539 MW.

[5] It is about twice as much as the current total installed capacity of Turkey!

[6] It is more than the current total electricity consumption of Turkey!

[7] When we take into account the fact that the total installed capacity of Turkey is currently 40,843.5 MW [19], this figure seems to be extremely unlikely.

Table 7
The top five world wind energy markets in terms of installed wind capacity (MW).

Country	2000	2001	2002	2003	2004	2005
Germany	6,113	8,754	12,001	14,609	16,629	18,428
Spain	2,235	3,337	4,830	6,202	8,263	10,027
United States	2,554	4,275	4,685	6,374	6,740	9,149
India	1,167	1,407	1,702	2,110	2,985	4,430
Denmark	2,300	2,417	2,880	3,110	3,117	3,128

Table 8
Wind potential of European OECD countries.

Country	Territory (thousand km^2)	Specific wind potential (class >3) (thousand km^2)	Side potential (km^2)	Technical potential	
				MW	TWh/year
Turkey	781	418	9,960	83,000	166
UK	244	171	6,840	57,000	114
Spain	505	200	5,120	43,000	86
France	547	216	5,080	42,000	85
Norway	324	217	4,560	38,000	76
Italy	301	194	4,160	35,000	69
Greece	132	73	2,640	22,000	44
Ireland	70	67	2,680	22,000	44
Sweden	450	119	2,440	20,000	41
Iceland	103	103	2,080	17,000	34
Denmark	43	43	1,720	14,000	29
Germany	357	39	1,400	12,000	24
Portugal	92	31	880	7,000	15
Finland	337	17	440	4,000	7
The Netherlands	41	10	400	3,000	7
Austria	84	40	200	2,000	3
Belgium	31	7	280	2,000	5
Switzerland	41	21	80	1,000	1
Luxemburg	3	0	0	0	0

speed and annual average wind energy potential of various regions of Turkey are shown in Table 11. The annual average wind speeds range from a low of 2.1 m/s in the East Anatolia region to a high of 3.3 m/s in the Marmara region. The most attractive regions for wind energy applications are the Marmara, the southeast Anatolian and the Aegean regions. These regions are highly suitable for wind power generation, since the wind speed exceeds 3 m/s in most of these areas [2].

As can be seen in the tables, currently, wind capacity is only 0.4% of total capacity and production is a mere 0.08% of total generation in Turkey!

3.3. Current Turkish legislation on wind energy

Existing Turkish law and regulation with relevance to the use of renewable energy sources is limited to two pieces of legislation. One piece of legislation is the Electricity Market Licensing Regulation, and the second is the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy (Law Number 5346, dated May 10, 2005). As indicated by the titles, this legislation has been developed for the electricity sector. In both regulations, wind power is included in the definition of renewable energy resource. There is no legislation currently existing for wind power alone.

In Turkey, market based policies for renewables started in 1984 with third-party financing, excise and sales tax exemptions. Capital grants were offered in 2001. The Turkish government's approach to the deployment of renewables reveals its priorities to develop indigenous and renewable resources in conjunction with

Table 9
Renewables indicators by country for 2004.

Country	TPES (total primary energy supply) (Mtoe)	Primary supply from renewable sources (Mtoe)	Renewable share in TPES (%)
Paraguay (incl. exports)	4.0	6.6	164.9
Philippines	44.3	20.2	45.6
Brazil	204.8	82.0	40.0
India	572.9	222.0	38.8
Pakistan	74.4	28.7	38.6
Norway	27.7	10.6	38.4
Sweden	53.9	13.9	25.7
Finland	38.1	8.8	23.0
Austria	33.2	6.7	20.1
Thailand	97.1	16.4	16.9
China	1,626.5	251.0	15.4
Canada	269.0	41.4	15.4
Switzerland	27.1	4.1	15.1
Portugal	26.5	3.8	14.3
Denmark	20.1	2.7	13.6
Turkey	**81.9**	**10.8**	**13.2**
Total World	**11,058.6**	**1,447.9**	**13.1**
Spain	142.2	8.8	6.2
Italy	184.5	11.2	6.1
France	275.2	16.3	5.9
Total OECD	5,507.9	315.0	5.7
Australia	115.8	6.4	5.5
Greece	30.5	1.6	5.1
Poland	91.7	4.3	4.7
United States	2,325.9	98.6	4.2
Germany	348.0	13.2	3.8
Israel	20.7	0.7	3.5
Japan	533.2	17.3	3.2
Former USSR	979.3	29.8	3.0
Russia	641.5	18.9	2.9
Netherlands	82.1	1.7	2.0
United Kingdom	233.7	3.5	1.5
Islamic Republic of Iran	145.8	1.7	1.2
Saudi Arabia	140.4	0.0	0.0

the expansion of privately owned and operated power generation from renewable sources. The build-own-transfer (BOT) and the build-own-operate (BOO) schemes were put in place in 1984 and financed major power projects (not limited to renewables) with the main objective of attracting private investors. BOT projects were granted a treasury guarantee. Although BOT and BOO approaches attracted significant investment, they also created large public obligations with the government covering the market risk through take-or-pay contracts. The BOT and BOO financing schemes ended in 2000 and were replaced in 2001 by financial incentives within the framework of the Electricity Market Law (Law Number 4628).[8]

According to the Electricity Market Licensing Regulation, promotion of renewable energy sources in the electricity market has been assigned to the Energy Market Regulatory Authority (EMRA). Specifically, the Regulation states that the issues assigned to the Energy Market Regulatory Authority are "*With regard to the environmental effects of the electricity generation operations, to take necessary measures for encouraging the utilization of renewable and domestic energy resources and to initiate actions with relevant agencies for provision and implementation of incentives in this field*". In this context, there are some incentives and regulations related to renewable energy sources. The incentives brought into existence based on the Electricity Market Licensing Regulation are given below:

[8] Before the Electricity Market Law, the price of energy was decided as a result of negotiations between the energy production companies and the state, which is the buyer. For more information on the subject, see Erdogdu [20].

- Entities applying for licenses for construction of facilities based on domestic natural resources and renewable energy resources shall pay only 1% of the total licensing fee.
- The generation facilities based on renewable energy resources shall not pay annual license fees for the first 8 years following the facility completion date indicated on their respective licenses.
- Turkish Electricity Transmission Company (TEIAS) and/or distribution companies shall assign priority for system connection of generation facilities based on domestic natural resources and renewable resources.

The aim of the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy is to increase the use of renewable energy sources for generating electrical energy, as well as to diversify energy resources, reduce greenhouse gas emissions, assess waste products, protect the environment, and develop the necessary manufacturing sector for realizing these objectives. Specific incentives introduced in the law that are applicable to the use of wind power include:

- *Obligation to purchase electricity from renewable energy sources:* Each legal entity possessing a retail sale license shall be required to purchase renewable energy source-certified (RES-certified) electricity in an amount declared by EMRA.
- *Purchasing of electricity from renewable energy sources with a higher price:* Until the end of 2011, the applicable price for the electricity to be purchased in pursuance with the law within each calendar year shall be the Turkish average wholesale electricity price in the previous year determined by EMRA. However, this price shall be between 5 and 5.5 Eurocent/kWh. The Council of Ministers is entitled to raise this price up to 20% at the beginning of each year.
- *Acquisition of land:* In the case of utilization of property which is under the possession of Forestry or Treasury or under the sovereignty of the State for the purpose of generating electricity from the renewable energy resources included in the law, these territories are permitted on the basis of its sale price, rented, given right of access, or usage permission by the Ministry of Environment and Forestry or the Ministry of Finance. A 50% deduction shall be implemented for permission, rent, right of access, and usage permission in the investment period.

3.4. International aspect

Since the 1970s, rising concern for global environmental degradation has led to wide acceptance of sustainable development concept. Following its initial popularization, the concept of the sustainability has appeared in a wide range of forms in recent literature. Although different authors have given it a variety of meanings, sustainable development is best defined as *meeting the needs of the present generation without compromising the ability of future generations to meet their own needs* [15]. In this context, sustainability is used to characterize the desired balance between economic growth and environmental preservation.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change, agreed to in December 1997, marks an important turning point in efforts to promote the use of renewable energy worldwide. Since the original Framework Convention was signed at the Earth Summit in Rio de Janeiro in 1992, evidences of climate change have spurred many countries to increase their support of renewable energy. Even more ambitious efforts to promote renewables (including wind power) can be expected as a result of the Kyoto pact, which includes legally binding emissions limits for industrial countries, and for the first time, specially identifies promotion of renewable energy as a key-strategy for reducing greenhouse gas emissions.

Table 10
Wind power in Turkey.

Years	Production and consumption (GWh)		Installed capacity (MW)		Share of wind power in total consumption (%)	Share of wind power in total installed capacity (%)
	Wind power production	Total power consumption	Wind power installed capacity	Total installed capacity		
1998	6	114,023	9	23,263	0.005	0.039
1999	21	118,485	9	26,125	0.018	0.034
2000	33	128,276	19	27,264	0.026	0.070
2001	62	126,871	19	28,332	0.049	0.067
2002	48	132,553	19	31,752	0.036	0.060
2003	61	141,151	19	35,564	0.043	0.053
2004	58	150,018	19	36,824	0.039	0.052
2005	59	160,794	21	38,820	0.037	0.054
2006	127	174,230	59	40,519	0.073	0.146
2007	?	?	161	40,755	–	0.395

Table 11
Wind potential of various regions in Turkey.

Region	Annual average wind speed (m/s)	Annual average wind density (W/m^2)
Marmara	3.3	51.9
Southeast Anatolia	2.7	29.3
Aegean	2.6	23.5
Mediterranean	2.5	21.4
Black Sea	2.4	21.3
Central Anatolia	2.5	20.1
East Anatolia	2.1	13.2
Turkey average	2.5	24.0

In October 2005, EU opened accession negotiations with Turkey, who has been an associate member of the EU since 1963 and an official candidate since 1999. There are many policies, directives, standards and norms in the EU designed to stimulate and support the wind power industry. Currently, Turkey is not required to comply with the EU norms but in the near future she will be obliged to do so in the course of accession negotiations.[9]

3.5. Barriers to wind energy exploitation in Turkey

The most important barriers for the exploitation of wind power in Turkey are summarized below:

- establishment of a structure at the institutional level, which requires a higher level of coordination and cooperation within and between institutions, agencies, institutes, and other stakeholders,
- insufficient available information about existing and possible future costs of wind power utilization,
- insufficient detailed wind energy resource assessments and data banks pertaining to Turkey,
- insufficient credit facilities, particularly for small-scale projects,
- administrative and time-consuming obstacles for foreign investors,
- need for support for infrastructure and management know-how at a local level,
- insufficient participation by the private sector,
- need for staff with sufficient technical information,
- difficulties possibly encountered in planning, project feasibility, and project control activities,
- insufficient policy instruments in the sector,
- need for public acceptance and willingness,
- technology risks.[10]

4. Wind energy economics

The economics of wind-generated electricity depends on several factors. Cost is primarily technology driven and is influenced by production technology. By far the most significant factors that contribute to wind energy value are related to the wind resource and the characteristics of the grid and the evolving market rules. As additional wind capacity is developed, these variables will be quantified more precisely.

A cost comparison between wind energy and other energy production methods is shown in Table 4. From this it can be seen that wind energy is as economically usable as other common energy sources. Also, a 20-turbine wind farm can be established on a 1 km^2 field. When compared to other power stations, a wind farm uses only 1% of its total site. This allows agricultural activities to be done around the turbines, which highly reduces the land cost of the wind power production. As can be seen in Table 5, wind power is almost the least expensive one among renewable sources in terms of both investment and generation cost.

5. Evaluation of wind energy use

5.1. Benefits of wind energy use

Clean, domestic and renewable energy is commonly accepted as the key for future life, not only for Turkey but also for the world. This is primarily because renewable energy resources have some advantages when compared to fossil fuels. Wind energy is domestic, independent to abroad, natural and infinite, obtained in the future as same amount, does not cause acid rain or atmospheric heating, no CO_2 emission, no harm to nature and human health, providing fossil fuel saving, no radioactive effect, fast technological development and currency gaining sources. Some of the most important benefits of wind energy are discussed below.

5.1.1. Lower emissions to the environment

Wind power appears to have formidably positive environmental properties, resulting in no releases of carbon dioxide and

[9] For a more detailed discussion of EU–Turkey relations, see Erdogdu [21].

[10] While improved technology may be able to battle some of the elevated investment costs of wind energy, technology risks remain. Some relevant technology is proven, however a lot of technology remains in research, development, and demonstration phases. This technology risk is considered unacceptable to some investors.

sulfur content. The most important gain of wind power utilization is the environmental benefit of displacing fossil fuel usage and a reduction in any adverse environmental impacts that are caused by fossil fuel consumption. Measured gaseous pollutants emissions for various fuel types such as CO_2, CH_4, NO_x and SO_2 are presented in Table 12. The figures shown in Table 12 are based on the lifecycle assessment technique, and indicate gaseous emissions emitted during the whole process [6]. As indicated by Table 12, the smallest environmental loads are due to hydropower, wind, geothermal and nuclear power plants. Among organic fuels, ecologically the most advantageous one is natural gas, although it is behind nuclear power and hydropower, while coal and oil burning is still the source of significant environmental pollution. During the operation of power plants with renewable energy sources such as photovoltaic (PV) cells, wind or hydropower plants, there are no emissions and the environmental loads are small. The main environmental burdens for renewable energies are due to the balance of lifecycle – namely, due to the material and equipment production and power plant construction.

The environmental benefits of wind power are felt locally, regionally and globally. Wind power can displace power from fossil fuel-powered plants, and thereby help to improve local air quality, mitigate regional effects such as acid rain, and reduce greenhouse gas emissions. Power plants emit pollutants as a by-product of power generation, but also may account for further emissions in connection with plant construction, operation, and decommissioning. For example, the mining and transport of fuel are themselves energy-intensive activities, with associated emissions and environmental impacts. Wind compares favorably to traditional power generation on this metric as well. Lifecycle CO_2 emissions per unit of power produced by a wind farm are about 1% of that for coal plants and about 2% of that for natural gas facilities [2].

We clearly see the necessity for seriously considering renewable energy sources when we examine the environmental impact associated with other possible sources. The abundant fossil fuels, such as coal, are often damaging to the environment throughout the fuel cycle, from mining to processing to consumption. Fossil fuels also carry the threat of global climate modification through increased discharge of carbon dioxide, particulates and other materials. Nuclear energy, while imposing no threat of climate modification, is associated with serious problems, such as waste disposal, accidents and weapons proliferation. Nuclear energy also releases waste heat into the environment through on site cooling processes and through transportation and use of the electricity it produces.

In short, continuous uses of fossil fuels are bound to pollute the atmosphere and consequently unwanted greenhouse and climate change effects will come to dominate every part of the earth. It is, therefore, vital to exploit clean energy resources, and for many nations in the world to try to assess their environmentally friendly, clean energy resources such as wind energy.

Table 12
Main gaseous pollutants (g/kWh).

Fuel type	CO_2	CH_4	NO_x	SO_2
Nuclear	17	–	0.047	0.072
Geothermal	21	0.059	–	–
Hydropower	32	0.135	0.056	0.055
Wind	38	0.169	0.055	0.071
Biomass, wood burning only	–	–	0.350	0.087
Solar (PV cells)	319	0.883	0.408	0.494
Natural gas	386	1.076	0.351	0.125
Oil	760	4.216	0.622	0.314
Coal	838	4.716	0.696	0.351

5.1.2. Contribution to security of supply and sustainability

Sustainable energy can be developed by laying more emphasis on domestic resources in the energy mix. In recent years, Turkey has begun to ignore the importance of energy usage based mainly on domestic sources. Today, about 78% of the Turkey's energy consumption is met by imports. The reliance on import resources – particularly on natural gas – to such an extent threatens the essentials of the sustainable development model seriously. In this context, wind power contributes to Turkey's energy diversification strategy.

5.1.3. Development of competition in energy market

Wind power presents an opportunity to move towards more decentralized forms of electricity generation, where a plant is designed to meet the needs of local customers, avoiding transmission losses and increasing flexibility in system use; which in turn provides an opportunity to increase the diversity of power generation plants, and competition in electricity generation.

5.2. Drawbacks of and obstacles to wind energy use

Nonetheless, as seen below, there are many barriers and obstacles that slow down the progress of wind power technology diffusion into power industry. Some of these barriers have general character that stay before power industry as a whole. Others possess narrow character typical only for wind power [11]. Among formers are:

- The necessity for regulatory reforms in energy sector;
- Creation of a kind of effective "High National Energy Council";
- The active participation of the relevant factors in the energy policy making process;
- The integration of domestic energy sectors in international market and privatization;
- Close cooperation of the state bodies with scientific organizations, private sector, public associations, political parties, and interest groups in the process of planning;
- Necessity of developing various contemporary scientific models for energy planning.

The latter barriers include:

- Definition of the specific place of renewable energy sources in the overall energy politics;
- Reinforcement of infrastructure of electrical networks at high wind locations as a matter of priority;
- Revision of legal framework for independent power producers to address the realities of the present and demands of the future.

In addition to above-mentioned ones, some other problems associated with wind energy utilization are presented below.

5.2.1. High cost of wind energy production

Generally speaking, wind power production cost is currently higher than that of the classic fuels (see Table 4). However, it is better to keep in mind that cost comparisons are highly subject to fluctuations and the continuous efforts for the advances in wind power production technologies may make this cost relationship more favorable for wind energy.

5.2.2. Technical concerns

Large-scale use of wind power plants can pose challenges to power system operations and planning. Because wind is an intermittent power source that is available only when the wind blows, the economics surrounding the use of this technology can become

Table 13
Environmental impacts as source type.

Source	Contribution into emissions, air pollution and climate change	Contribution into water pollution and watery areas	Waste	Visual impacts	Noise	Impacts on habitat and living life
Fossil fuels	+	+	+	–	+	+
Solar	–	–	–	+	–	–
Wind	–	–	–	+	+	+
Geothermal	–	+	–	–	+	+
Hydrogen	–	+	–	–	–	–
Ocean-wave	–	+	–	+	+	+
Biomass	+	–	+	+	–	–

complicated. The introduction of intermittent renewable energy sources, principally large quantities of wind power, can affect optimal grid performance. Problems could occur either when wind capacities are providing too little or too much power. Moreover, because wind systems cannot respond to control systems in the same way as can conventional thermal plants, questions arise concerning the need for storage or other mechanisms to integrate wind into the electrical supply. Other questions concern the ability to measure the wind plant capacity in a way that helps decision makers to analyze economic trade-offs between wind and other types of power plants. Technical solutions and business and regulatory practices are being developed in some countries to help the integration of large wind capacities.

5.2.3. Public opposition

Public opposition to new wind projects has been increasingly mobilized. Not In My Back Yard (NIMBY) is a growing social issue for wind power development. New locations, especially offshore and in non-surveyed terrain, may be mapped and assessed to reduce the visual impact on sensitive populations. Internationally accepted requirements for noise conditions should be developed in order to reduce public opposition.

5.2.4. Environmental impacts

The primary environmental concerns with wind power are related to potential visual, auditory, locational and wildlife impacts of wind farm installations. Electromagnetic interference with television and radio signals within 2–3 km of large installations also creates some problems. However, these concerns can be addressed through proper sitting, public education, and the use of improved technologies. Wind farms may be located away from wildlife refuges and residential areas to prevent such impacts.

Environmental impacts that resources used in energy generation have occurred during production are shown in Table 13 [2]. In table, it is used "+" in case of being stated impact of source. It is used "−" in the event of not being or little being stated impact of source. It is examined whether or not there is only an impact of source. Therefore, marks in the table are relative.

On land, wind turbines are located where the wind resource is best – typically in highly visible, exposed locations. Offshore wind parks, likewise, are usually situated within sight of the shore. In both cases, the vertical towers and the motion of the rotors cause the wind turbines to become focal points in the landscape for observers close to the wind towers.[11] Plus visual impacts, wind energy is associated with other environmental issues such as noise,[12] land use and impacts during the construction phase. Relative to other forms of energy development, most commercial wind farms occupy a large amount of space. Although the turbine pads occupy little ground area, the developments often must be spread over many miles. For wind developments, issues of habitat[13] concern:

- Outright loss of a species' habitat due to development (e.g., removing trees),
- Indirect impacts due to disturbance (i.e., the animals will no longer reside near the development),
- Disruption in animal passage through or over the development due to the addition of towers and turbines.

Final concern to be addressed if wind turbines are installed in close proximity to inhabited areas relates to shadow flicker, the effect caused by rotating blades cutting through sunlight. Modern commercial wind turbines are tall structures that will cast a shadow at certain times of the day. Concerns about shadow flicker can be minimized or eliminated with careful wind farm layout and sufficient setbacks from residences.

6. Guidelines for policy makers

The overall objective of energy-related policies should be ensuring sufficient, reliable and affordable energy supplies to support economic and social development, while protecting the environment. Therefore, when choosing energy fuels, it is essential to take into account economic, social and environmental consequences. In the past, environmental impacts of energy resources were ignored or not foreseen, while energy policies focused on adequate supply of energy to assure high rates of economic growth. Today, besides the economic issues, particular importance should be assigned to environmental factors associated with the choice of energy sources.

In Turkish case, as fossil fuel energy becomes scarcer, Turkey will face energy shortages, significantly increasing energy prices, and energy insecurity within the next few decades. In addition, Turkey's continued reliance on fossil fuel consumption will contribute to accelerating the rates of domestic environmental quality and global warming. For these reasons, the development and use of renewable energy sources and technologies are increasingly becoming vital for sustainable economic development of Turkey [16].

Prospective policy instruments and guidelines appropriate for Turkey concerning wind power utilization may include:

- Turkey, first of all, must develop and publicize a rational and coherent energy policy and an action plan; stating short, middle and long term aims, actions and reasons that justifies them. Then,

[11] Determining whether a wind farm creates visual pollution is purely subjective and, therefore, is difficult to quantify.

[12] Some of the wind energy captured by wind turbines is unavoidably transformed into sound energy. Air moving by the rotors generates sound, though improvements in rotor technology have greatly diminished the amount of sound produced in this way.

[13] The term "habitat" refers to the specific configuration of environmental features (e.g., vegetation, rock outcrops, water) that an animal uses at any point in time.

the specific place of renewable energy sources in the overall energy politics of Turkey should be defined in this plan. Also, a kind of effective "High Energy Council" must be set up to provide a higher level of coordination and cooperation within and between institutions, agencies, institutes, and other stakeholders. If not, it is not possible for Turkey to develop in a sustainable way and all other guidelines given below lost their meanings.

- Existing Turkish legislation on wind power should be developed in compliance with EC directives.
- Existing legislation, on paper, is enough to encourage the generation of wind power in Turkey. However, it is not the case for implementation. Responsible bodies (especially market regulator, EMRA) should question the logic of their actions. For instance, up to now, EMRA has issued licenses for about 2500 MW wind power capacity and accepted license applications for a total capacity that almost equals twice of the total installed capacity of the whole country (!); however, currently, she has only 200 MW wind power installed capacity in operation. Moreover, accepted license applications mostly overlap in terms of the plant site. Responsible bodies in Turkey must form their policies and actions in a logical manner.
- Turkey should establish a target (e.g., 10%) for the penetration of renewable energy sources into the domestic energy consumption by a given year. It could also include a separate but integrated target for wind power alone.
- A target for the penetration of wind power into the energy market by a given year should also be established, potentially with interim targets to ensure the country stays on track with the goal.
- A program should be prepared to support the advancement in technology with regard to both the supply and demand sides of wind power. Turkey should also invest to the wind turbine technology both for using its wind potential more cheaply in a long period and for supplying job opportunity to the people.
- In the light of the data available, it seems that Turkey is a suitable country in which to establish wind fields. Projects, subject to regional conditions, should be started in regions that offer productive wind energy potential.
- Turkey should create the favorable conditions for wind power manufacturing factories, which allows creating new work places on one hand and reducing transportation expenses on the other hand.
- More detailed wind energy resource assessments and data banks pertaining to Turkey should be prepared.
- Administrative and time-consuming obstacles for foreign investors should be eliminated.
- Some public campaigns should be carried out to meet the need for public acceptance and willingness.
- Since a wind farm uses only 1% of its total site, some agricultural activities should be encouraged around the turbines, which highly reduces the land cost of the wind power production.
- The infrastructure of electrical networks at high wind locations should be reinforced of as a matter of priority. Turkey should also draw some lessons from technical solutions and business and regulatory practices developed in some countries to help the integration of large wind capacities into main electricity infrastructure of the country.
- Wind farms should be located away from wildlife refuges and residential areas to prevent public opposition. Internationally accepted requirements for noise conditions should also be developed in order to reduce noise pollution.
- Concerns about shadow flicker should be minimized or eliminated with careful wind farm layout and sufficient setbacks from residences.

Finally, although the immediate priority of Turkey should be to speed the transition from the reliance on non-renewable fossil fuels to reliance on renewable energy sources, policy makers must be aware of the fact that renewable sources are alone not enough to meet the rapidly increasing energy demand in Turkey. Therefore, policy makers should seriously consider some other alternative energy sources, including nuclear power.

7. Conclusion

Wind power provides a clean, renewable energy source that could dramatically improve our environment, economy and energy security. Wind power generates far less (almost none) air emissions than fossil fuels and decreases the reliance on imported energy. Today, in most ways, wind power has come of age; the technology has improved, the economics has become more appealing, and substantial progress has been achieved in reducing environmental impacts.

Turkey is an energy-importing country. In order to be less dependent on other countries, Turkey needs to use its sustainable sources. From this point of view, wind power is a very attractive choice, since it is economical, sustainable, environmental friendly and a familiar energy source in Turkey. Furthermore, Turkey has several advantages for the use of wind power in terms of its location. However, today, in Turkey, the domestic consumption of wind power is lagging, mainly due to economic barriers, lack of legislative and regulatory framework and poor infrastructure.

While specific policies and regulations are recommended here, it is also important for efficiency and effectiveness that communication and mechanisms for coordination/cooperation between ministries (i.e., energy, and environmental) and other related institutions (e.g., EMRA) be improved.

The private sector, which has the capacity to mobilize needed funds, must be motivated to participate in wind power and other renewable energy development. The process of liberalization, restructuring, and privatization in the Turkish energy sector[14] is also vital; which will assist in creating a favorable environment for investment in wind power.

To sum up, in Turkey, wind power represents a secure domestic source of energy that is not subject to the price fluctuations and supply uncertainties of imported petroleum and natural gas. Future supply of wind energy depends on energy prices and technical progress, both of which are driven by energy policy priorities.

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